ORIGINAL ARTICLE

Q1 Artificial Intelligence and the Trainee Q2 Experience in Radiology

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Abstract

The hype around artificial intelligence (AI) in radiology continues unabated, despite the fact that the exact role AI will play in future radiology practice remains undefined. Nevertheless, education of the radiologists of the future is ongoing and needs to account for the uncertainty of this new technology. Radiology residency training has evolved even before the recent advent of imaging AI. Yet radiology residents and fellows will likely one day experience the benefits of an AI-enabled clinical training. This will offer them a customized learning experience and the ability to analyze large quantities of data about their progress in residency, with substantially less manual effort than is currently required. Additionally, they will need to learn how to interact with AI tools in clinical practice, and more importantly, understand how to evaluate AI outputs in a critical fashion as yet another piece of information contributing to the interpretation of an imaging examination. Although the exact role AI will play in the future practice of radiology remains undefined, it will surely be integrated into the education of future radiologists.

Key Words: Artificial intelligence, radiology education, radiology residency

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INTRODUCTION

A great deal of attention is being paid to artificial intelligence (AI) in radiology, and with it comes a substantial amount of uncertainty and hype. Exactly what role AI will play in the future practice of radiology remains undefined. As a result, there is also uncertainty about how it will affect radiology residency training. Nevertheless, there are many potential ways AI could be used to teach future radiologists. The recent attention paid to AI and its capacity to detect imaging findings has measurably affected medical students' perception of the field [1-3]. Framing the discussion of how AI will affect the trainee experience in the context of how radiology residents and fellows are taught today may serve to reassure future radiology residents that they will have a meaningful career augmented by AI.

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CURRENT APPROACHES TO RADIOLOGY EDUCATION

The ACGME has substantial oversight of radiology resident education and has a set of common requirements for all residency programs. One of the goals implicit in the requirements is to facilitate the development of resident knowledge, skills, and values required to take ownership of patient care [4]. ACGME requirements specific for radiology resident education, how residency programs may satisfy those requirements, as well as some educational trends in providing residents with educational resources, didactics, workday teaching, and feedback will be discussed.

Educational Resources

ACGME requires that all radiology residency programs have sufficient learning resources available to trainees [1]. This includes readily available access to specialty specific material in electronic or format that must be able to support the number of residents within the radiology residency program. Radiology residencies can achieve this

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in several ways including purchasing literature, online resources, and providing access to university libraries.

Learning materials are conventionally in the form of textbooks, though review articles, online self-assessment platforms, and educational videos have been growing in popularity and may be preferred by some residents [5]. Most residency programs provide textbook recommendations and chapter-specific assignments for each rotation. However, reading, rereading, and highlighting textbooks may be a less effective form of learning [6,7]. This could be improved when reading becomes a more active process, whereby learners self-quiz, pause to consolidate information, and contrast disease processes [8-10]. Educational videos may be more useful to some learners and are becoming increasingly available from both radiology societies and commercial entities. Videos under 15 min have been growing in popularity due to their limited scope, which may make the information feel more digestible. Review articles are preferred by some residents due to ease of online access [11]. As a result, some residency programs provide not only textbook-specific reading recommendations but also suggestions for resident-appropriate video content and article collections.

Testing and retrieval-based strategies, in comparison with textbook reading, have been shown to be more effective in improving knowledge retention. Online question banks are growing in popularity both for learning and resident assessment [12]. Online platforms in comparison with textbooks and articles are also more dynamic. These learning platforms allow for the creation of curated case sets to meet the educational needs of a learner. Cases can be arranged by subspecialty, modality, or disease process depending on learner needs. Online platforms also interleave cases that users have previously answered incorrectly, increasing the likelihood that users address knowledge deficiencies [13].

Radiology residency programs are also required by the ACGME to have rotation-specific goals and objectives that are readily available to all residents [1]. These can be institution specific or adopted and modified from national societies. For instance, the American Society of Thoracic Radiology has published learning guidelines for residents rotating through cardiothoracic imaging. The guidelines are comprehensive and structured, providing programs that may not have robust subspecialty imaging sections guidance from experts in the field.

Didactics

Protected didactic time for residents in training is required by the ACGME. It is expected that residents participate in structured didactic activities, which are broadly defined and can include lectures, conferences, asynchronous learning, simulations, and case discussions [1]. Most residency programs provide a daily lecture series, with topics divided among radiology subspecialties. Lectures are often 45 to 60 min and delivered as a slide presentation. This approach can be powerful when used effectively. However, presentations run the risk of being text-heavy, leading some lecturers to read directly from slides with little audience participation. Attention of learners typically wanes when content is delivered in this fashion, and knowledge retention also tends to be poor compared with other learning methods [14,15].

Lectures can be redesigned to increase learner retention and understanding [16-19]. The flipped classroom assigns trainees a prelearning assignment before the didactic, such as an article or video. In class, participants have the chance to apply learned concepts from the prelearning under the instruction of the lecturer. This process allows for corrective feedback from an expert and the chance for learners to flush out concepts. It also gives them an opportunity to learn from and teach their peers. Applying the flipped classroom to medical students rotating through a radiology clerkship has shown promise. Although there were no baseline differences in test scores between students in the flipped classroom and traditional lectures, flipped learning was associated with greater task value, increased academic achievement, and more positive emotions [20].

Software has also been developed that may lead to more engaging lectures. Polling software can seamlessly integrate with slide presentations and provide a real-time, graphical representation of answer choices for questions posed to the audience. The RSNA Diagnosis Live application (https://live.rsna.org/) allows speakers to upload images so that participants can answer questions on their personal devices as well as interact with radiology images by selecting the abnormality [21,22]. Commercial tools also exist for either computers or tablets that simultaneously allow the speaker and one or more participants to draw on the lecturer's slides from separate devices [23]. This can be particularly helpful for case conferences, where residents can circle or outline abnormalities.

Learning During the Workday

ACGME requires that a sufficient number of faculty be present to instruct and supervise all residents [4]. These faculty members must be role models of professionalism, demonstrate strong interest in resident education, and administer and maintain an educational environment conducive to educating residents [4]. Learning from faculty during the workday is usually more experiential

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and mainly occurs when residents review examinations under the guidance of an expert radiologist at a PACS reading station. Learning in this setting is influenced by two elements: the educational ability of the supervising radiologist in conjunction with resident learning preference and the cases that are available for interpretation. Pairing of residents with an attending radiologist may be arbitrary and dictated by work schedules rather than educational styles and personalities. Some attention is usually given to resident case mix and work volume, although resident case exposure is usually driven by worklist assignments developed for predominately clinical rather than educational needs. ACGME does have a required minimum number of modality-specific cases to be logged for residents over the course of their training [24].

During a rotation, a resident may be instructed to focus on studies that ready them for call (pulmonary embolism, traumas, stroke alerts) or a modality that they have graduated to (MRIs). Work volume expectations may also be set. However, both volume and case mix are determined by referring providers and the imaging center's capacity. Surveillance oncologic imaging may represent the majority imaging during the workday, limiting residents' exposure to other disease processes as well as the supervising radiologist's ability to address potential educational deficiencies. Radiology worklists are also limited in their ability to parse out interesting or potentially educationally noteworthy studies that could foster discussion and resident assessment. As a result, residents may not encounter some diseases or imaging modalities frequently enough to feel proficient.

Radiology residencies have tried to address this by creating teaching files arranged by modality, specialty, or disease process. Radiology case-based simulations have been developed to round out resident experiences and call preparedness. Vendor-neutral digital teaching files allow radiologists to upload anonymized imaging studies from PACS with minimal disruption to clinical workflow [25]. Cases can be labeled, grouped into decks, and authored to highlight relevant teaching points. Case-based simulations in preparation for call have been shown to at least create a subjective feeling of preparedness for trainees [26].

Resident Evaluation and Feedback

The ACGME requires training programs to maintain a learning environment conducive to educating residents in each of the six core competencies: professionalism, patient care and procedural skills, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, and systems-based practice [4]. These core competencies provide a framework in developing physicians entrusted to enter autonomous practice. Residency-specific milestones were created to assess residents' trajectory during their training in each of these six competencies and are used during ACGME-required clinical competence committee's semi-annual review of resident performance [27]. Milestone performance data for each program's residents are an element used in the ACGME's Next Accreditation System to assess if residents are progressing and identify which residency programs are flourishing or struggling [28]. Information from this national database can identify programs that are doing well to help establish best practices and provide aid to those having difficulty [29].

During their training, residents may progress through five levels of milestones for each core competency. These levels do not necessarily correspond to years of training, such that a third-year resident does not have to be a level 3, and a junior resident may be at a higher milestone compared with a senior. Residents could also regress in milestone levels. Level 4 is designated as a graduation goal but is not a requirement for graduation, which is at the purview of the residency program director. Level 5 is considered to be an expert resident who has surpassed expectations.

Core competencies are further divided into subcompentency categories. For instance, "Patient Care" has four subcompetency categories (reporting, clinical consultation, image interpretation, and competence in procedures) and systems-based practice has eight, each with five levels of milestones. Each milestone level has language specific for the subcompetency being assessed. For example, in level 1 of the subcompentency "Diagnostic Knowledge," the resident "demonstrates knowledge of imaging anatomy," whereas in level 5, the resident "proficiently integrates knowledge of anatomic and molecular imaging with pathophysiology to formulate a diagnosis at the expected level of a subspecialist." An updated version, Milestones 2.0, took effect in July 2020.

HOW AI MIGHT CHANGE THE RADIOLOGY TRAINEE'S EXPERIENCE

AI-Enabled Radiology Education

The future impact of AI in radiology is not limited to its role in findings detection or its potential impact on workflow efficiency [30]. AI also has the potential to take large quantities of data about resident education, performance, and progress through training and enable customization of the educational experience to the strengths and weaknesses of the individual trainee [31,32].

As newer educational methods permeate radiology (eg, flipped classrooms, virtual education), incorporation of AI into education delivery can offer new methods for residents

to learn clinical radiology. For example, as the concept of gamification becomes a part of radiology education [33], trainees can earn rewards in an online platform for completing activities, such as achieving ACGME milestones, interpreting certain numbers or types of examinations, or passing online educational modules. AI can be a useful adjunct in helping residents to track their progress through training, by automatically identifying activities that are completed or milestones that are achieved and logging these for each trainee. At present, the logging process tends to be entirely or almost entirely manual, and adds work for each individual resident to keep track of their completed activities [34,35].

In addition, many radiology residency programs provide feedback to residents on the discrepancies between their on-call interpretations and the final attending overread [36,37]. This feedback may take the form of a message back to the interpreting resident that is manually entered by the faculty member or a text tag inserted in the report that can be mined and sent to a summary dashboard. Regardless of the form, the information is intended to provide residents with the opportunity to review cases on which they missed or misinterpreted findings and provide a valuable learning opportunity. By analyzing radiology resident performance using AI, there is greater potential to provide personalized resident feedback on either the basis of daytime rotation performance or off-hours call performance. Discrepancies with respect to the final attending interpretation can be analyzed to identify trends that could be aligned with the types of errors that typically occur in reports [38]. In turn, these could be summarized across residents to provide a number of relevant cases for review. Residents have often expressed concern that the feedback they receive is graded inconsistently; for example, one radiologist's major discrepancy may be another's minor discrepancy [39]. AI can potentially standardize resident feedback by analyzing large volumes of historic discrepancy data and providing guidance to both trainees and faculty.

In addition to analysis of on-call interpretations, AI built into the dictation system could be used to identify areas of uncertainty that residents encounter while interpreting examinations during daytime rotations. Furthermore, this information could be used to tailor the types of examinations that a resident interprets by incorporating it into the reading work list [40]. For example, a resident who needs more experience with interstitial lung disease cases could preferentially receive these chest CTs on a given workday. Similarly, on a musculoskeletal radiology rotation, this would even out the distribution of joint cases and spine cases, such that the former is not preferentially dictated by the fellows, and the latter by the residents.

AI-Powered Radiologist Decision Support

Although a great deal of attention is focused on clinical decision support for physicians ordering imaging, considerably less attention is focused on radiologist decision support at the time of diagnosis. This conventionally takes the form of guidance regarding follow-up recommendations for lesions identified during interpretation of images [41]; however, AI could supply diagnostic support for both practicing radiologists and radiology trainees taking independent call [42]. One example of this is the use of Bayesian networks to offer differential diagnoses based on a set of described findings [43].

AI-Enabled Assessment of Radiology Trainees and Radiologists

In light of changes to the ABR licensure process for diplomates over the past decade, the potential role of AI in evaluating radiology trainees' preparedness for independent call and independent practice should also be considered. One study in the literature correlates USMLE examination scores with the likelihood for subsequent poor performance on the ABR examinations [44]. However, more real-time assessment of residents during their training would be extremely valuable for identifying areas for further improvement in advance of sitting for licensure examinations. In the future, one could envision adaptive examination of radiology trainees that is driven by AI to not only adjust to the level of knowledge of the candidate, but also to re-evaluate areas that may have previously been remediated [12]. Similar approaches could be applied for maintenance of certification as is currently required by the ABR [45].

Teaching Radiology Residents About AI

In addition to considering how AI will change the trainee experience, it is important to consider how, when, and to what extent we should teach radiology residents and fellows about AI itself. The literature suggests that at minimum, radiology trainees will need to know how to use AI in their clinical work to understand where it can play a role and how to interpret its output [46]. One survey of current radiology residents and faculty found that nearly 85% of respondents felt that an understanding of AI should be taught during residency, and 80% felt it was as important to learn as imaging physics [47]. Another survey of practicing radiologists showed that they did not feel like they knew enough about AI and also wanted to learn more, so they might also benefit from the same education provided to trainees [48]. The challenge in adding more required components to the radiology residency arises when deciding what to remove or shorten to make room in the curriculum for new knowledge. Radiology residents will

likely need to be exposed to AI-related education throughout residency, ideally in the form of dedicated sessions as well as integrated into clinical teaching, as is currently done with medical physics.

Potential Adverse Effects of AI

As with every new technology, there will be potential adverse effects of AI that need to be addressed proactively. One popular proposed use for AI is triaging cases with abnormalities to the top of the radiologist's worklist, or having AI label normal examinations as such and remove them from the worklist entirely [49,50]. Although there are obvious efficiency benefits associated with removing normal cases from the worklist [49,51], the impact on radiology training should not be ignored. Radiology residents learn how to identify abnormalities by first establishing a mental standard for the normal appearance of a particular organ when captured by a particular imaging modality. Diverting these cases away from residents early in their training will thwart the normal learning process that radiology residents experience and require this knowledge to either be imparted in a different way or to limit junior residents' exposure to AI triage tools. Another option would be to first teach junior residents the traditional methods of image interpretation before exposing them to AI; however, the practicality of this approach would have to be balanced against the pervasiveness of AI in clinical practice.

A new challenge in training future radiologists will be teaching residents and fellows to recognize AI errors [50-52]. At present, evaluating software postprocessing of
Q9 reconstructed images is primarily limited to reviewing measurements; these are generally easily recognized with training. However, AI errors may be more subtle, less predictable, and less repeatable, given the nature of the technology [52]. Susceptibility to automation bias—the idea that the computer is more correct than the human by virtue of being a machine—is greater when the human practitioner is less confident, and it could have a stronger impact on less experienced radiologists and radiology trainees [53]. Future radiology trainees will be taught to be mindful of automation bias, just as they currently learn to be wary of satisfaction of search [54,55].

In conclusion, as with new imaging modalities, PACS, and structured reporting, AI will undoubtedly require changes to radiology trainee education. However, there are many opportunities to integrate AI into the existing pathways for radiology residents and fellows. AI will be yet another noninterpretive skill that radiology residents will be required to know. Current and future radiology residents and fellows will need to know how to interpret AI outputs, in addition to knowing how to interpret images. They will need to understand how AI modifies the clinical workflow and be sensitive to AI outputs that seem unusual or incongruent. Although exactly what role AI will play in the future practice of radiology remains undefined, it will surely be integrated into the education of future radiologists.

TAKE-HOME POINTS

- Current educational approaches for radiology trainees include recommended readings, live and recorded lectures, and teaching at the workstation. Newer techniques such as flipped classroom sessions and polling can be used to enhance learning and the learner experience.
- AI has the potential to take large quantities of data about resident education, performance, and progress through training and enable customization of the educational experience to the strengths and weaknesses of the individual trainee.
- AI could supply diagnostic support for both practicing radiologists and radiology trainees taking independent call.
- Current and future radiology residents and fellows will need to understand how data should be curated for AI development, how AI tools can be developed, and how to interpret AI outputs, in addition to knowing how to interpret images.
- The radiologists of the future will need to understand how AI modifies the clinical workflow and be sensitive to AI outputs that seem unusual or incongruent.

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